

**PCT**WORLD INTELLECTUAL PROPERTY ORGANIZATION  
International Bureau

## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

<b>(51) International Patent Classification <sup>7</sup> :</b> <b>C12Q 1/00, G01N 35/00, 27/30, 27/327</b>	<b>A1</b>	<b>(11) International Publication Number:</b> <b>WO 00/28068</b> <b>(43) International Publication Date:</b> 18 May 2000 (18.05.00)
<b>(21) International Application Number:</b> PCT/GB99/03764 <b>(22) International Filing Date:</b> 11 November 1999 (11.11.99) <b>(30) Priority Data:</b> 9824627.5 11 November 1998 (11.11.98) GB <b>(71) Applicant (for all designated States except US):</b> CAMBRIDGE SENSORS LIMITED [GB/GB]; Downhams House, Downhams Lane, Cambridge CB4 1XT (GB). <b>(72) Inventors; and</b> <b>(75) Inventors/Applicants (for US only):</b> YON HIN, Bernadette [GB/GB]; Cambridge Sensors Limited, Downhams House, Downhams Lane, Cambridge CB4 1XT (GB). MCCANN, James [GB/GB]; Cambridge Sensors Limited, Downhams House, Downhams Lane, Cambridge CB4 1XT (GB). BLAIR, Neil [GB/GB]; 122 Limes Road, Hardwick, Cambridge CB3 7XU (GB). COX, Lorna, Jean [GB/GB]; Cambridge Sensors Limited, Downhams House, Downhams Lane, Cambridge CB4 1XT (GB). <b>(74) Agent:</b> GILL JENNINGS & EVERY; Broadgate House, 7 Eldon Street, London EC2M 7LH (GB).		<b>(81) Designated States:</b> AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).  <b>Published.</b> <i>With international search report.</i>
<b>(54) Title:</b> ELECTRODE STRIPS FOR TESTING SMALL VOLUMES  <b>(57) Abstract</b>  A test strip comprising a support carries an active electrode and a counterelectrode, and a layer of material within which a small volume of liquid to be tested can be distributed and provide contact between the electrodes, and wherein an analyte-specific reagent is coated on the material. The layer of material can conveniently be provided in the form of a tape from which sections can be cut or used sequentially.		

**FOR THE PURPOSES OF INFORMATION ONLY**

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece	ML	Mali	TR	Turkey
BG	Bulgaria	HU	Hungary	MN	Mongolia	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MR	Mauritania	UA	Ukraine
BR	Brazil	IL	Israel	MW	Malawi	UG	Uganda
BY	Belarus	IS	Iceland	MX	Mexico	US	United States of America
CA	Canada	IT	Italy	NE	Niger	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NL	Netherlands	VN	Viet Nam
CG	Congo	KE	Kenya	NO	Norway	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NZ	New Zealand	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	PL	Poland		
CM	Cameroon	KR	Republic of Korea	PT	Portugal		
CN	China	KZ	Kazakstan	RO	Romania		
CU	Cuba	LC	Saint Lucia	RU	Russian Federation		
CZ	Czech Republic	LI	Liechtenstein	SD	Sudan		
DE	Germany	LK	Sri Lanka	SE	Sweden		
DK	Denmark	LR	Liberia	SG	Singapore		
EE	Estonia						

## Electrode Strips for Testing Small Volumes

### Field of the Invention

This invention relates to electrode strips for testing small volumes of, say, whole blood.

### 5 Background of the Invention

Diabetes is one of the most common endocrine conditions. Sufferers must monitor their blood glucose level frequently. This is usually achieved by the use of small test strips which detect blood glucose.

Problems commonly experienced by users of these test strips are an  
10 inadequate amount of blood on the test strip and bad placement of the blood on the test strip. A number of devices have addressed this problem by using sample chambers that fill by capillary action. The sample is retained in close proximity to the electrodes which facilitate the measurement of the specific analyte in the sample; see EP-A-0170375 and US-A-5141868.

15 Such known devices comprise electrodes deposited on a non-conducting substrate, coated with a reagent system specific for the analyte of interest and housed within a cavity whose dimensions are sufficiently small to allow introduction of a sample, e.g. 2.5-3  $\mu\text{L}$  in volume, by capillary action. The extent to which these devices can be miniaturized is limited by both the  
20 manufacturing tolerances and the signal-to-noise ratio achievable with their chemistry.

US-5820551 discloses a test strip comprising a support carrying a working electrode and a counter electrode, and an enzyme and a mediator that are coated on the active electrode. A drop of whole blood can provide a  
25 conducting path between the electrodes, and the concentration of glucose in the blood can be determined. The active electrode is exposed to a whole blood sample without an intervening membrane or other whole blood filter.

WO-A-98/55856 (published after the priority date claimed for this Application) discloses an analyte-specific reagent coated on the conductive  
30 layer, and a monofilament mesh laid over the reagent and the reference electrode. A sample application area is provided at one edge of the mesh.

### Summary of the Invention

According to a first aspect of the present invention, a test strip comprises a support carrying an active electrode and a counterelectrode, and a layer of a material within which a small volume of liquid to be tested can be distributed and provide contact between the electrodes, and wherein an analyte-specific reagent such as one component of a redox reaction, e.g. an enzyme, co-factor or mediator, is coated on the material. In particular, the invention provides a test strip for blood glucose, in which the sample requirement is very small, and efficient reaction kinetics are achieved by the application of the reagents in a novel manner.

The reagent-coated material may itself be in tape form. According to a second aspect of the invention, a flexible tape is of a material within which liquid can be distributed and on which are coated discrete areas of at least one component of a redox reaction.

### Description of the Invention

In accordance with this invention, any one or more of the components of a redox reaction, e.g. an enzyme such as glucose oxidase or glucose dehydrogenase, a co-factor and a mediator may be applied to a mesh or membrane which is placed over the device. For the purpose of illustration only, the invention may be described with reference to an enzyme-coated mesh. Whichever component or components are used, when the sample is added, they are solubilised quickly and form an efficient reaction medium that can provide contact between the separate electrodes of the test strip. In this manner, the reaction will proceed rapidly and without diffusion barriers. This reaction configuration is particularly indicated in cases where the sample volume is low, the sample is viscous (such as with whole blood) and a rapid reaction is required.

In a typical embodiment of the invention, the sensor test strip consists of two electrodes, one of which acts as a working electrode and another which acts as a counter, reference electrode. The end of the working electrode that is exposed to the sample has a mediator in intimate contact with it. The test strip effectively provides a reaction chamber defined by these two electrodes

and an additional sheet, overlying the electrodes, which has been pre-coated with the redox enzyme and any necessary co-factor for that enzyme. The reaction chamber may also comprise further sheets of material and/or wetting agents, e.g. a surfactant, or cell-lysing materials (which may be placed in any one of the overlying sheets). In this manner, the active enzyme is not coated onto the conductor which forms the working electrode but is provided in a separate layer above it which, in turn, effectively forms the solution phase of the reaction chamber. When combined with lateral flow, conditions are created that approach efficient mixing in a stirred reaction chamber.

In an example of the invention, a silver chloride/silver reference/counter electrode is located adjacent to a carbon electrode. Typically, for this purpose, a pair of printed carbon electrodes is printed on a non-conducting substrate, and then silver/silver chloride is printed on one of the carbon electrodes to function as the reference/counter electrode. A non-conducting ink is printed over the carbon electrodes and the substrate, in order to define a portion of each electrode as a contact pad for insertion into a meter and another portion on each electrode away from the contact pad as the sensing area where the sample is received.

A mediator for the enzyme cofactor NADH is then prepared and deposited onto the electrode from aqueous solution by pipetting. A further layer containing NAD is then deposited onto the working electrode.

A monofilament mesh material is coated with a surfactant and then with a solution containing glucose dehydrogenase via pipetting, ink jet-coating or dip-coating, and is placed over the two electrodes to form a reaction chamber. This reaction chamber may be defined further by additional printing, or by the use of a top layer to form an edge fill cavity. For example, a second non-conducting ink printed on top of the mesh material, and then a cover tape is applied on top of the mesh in such a way as to leave an extended area of the mesh exposed for sample application.

The device allows the application of a small volume of sample (typically 1  $\mu$ L or less) to the mesh extension. This is followed by flooding of the device

sensing area with sample, bringing it into intimate contact with the measuring electrodes.

Devices having an edge fill are described in WO-A-98/55856. They can be simply adapted, in accordance with the present invention. In particular, reference may be made to Fig. 1 in WO-A-98/55856; components of this invention are the support (1), electrodes (2/3), mesh material (6) and tape (7); in addition, reagent is provided on the mesh material. Such a device can work by application at its edge, to a sample. This is particularly valuable in cases where it is difficult to extract the sample. Other configurations will be evident to one skilled in the art, including combinations of one or more of the cofactor, mediator or the enzyme coated onto the overlying mesh or membrane sheets. The choice of combination may on the reaction kinetics of the various compounds.

In another embodiment of the device, the enzyme or the mediator is coated on the sheet, the co-factor and the other of the mediator or the enzyme are coated onto the working electrode directly, and the sheet is capable of filtering the whole blood such that the active electrode sees a sample which is effectively free of whole blood cells. In this case, the haematocrit dependency of the result is substantially reduced. In this manner, the cell-filtering function of a selected membrane may be combined with the rapid kinetics of having the some or all of the active elements of the reaction (the enzyme, mediator and the co-factor) in the membrane, to produce a highly effective device.

In summary, according to the present invention, a device is constructed by depositing one or more of the reagents required for the quantitation of an analyte as a single or multiple layers on a fine mesh material or membrane; the deposited areas are of dimensions small enough to wet with a very small sample volume. The mesh or membrane can be used in both colorimetric and electrochemical devices.

A characteristic of this invention is that a reagent is applied precisely onto a target area on a woven material such as polyester or nylon or other porous membrane. In use, this provides rapid solubilisation of the reagents in the presence of the sample. The reagent or reagents can be applied in a

number of different methods that result in the deposition of a known volume at a precise location and in a well-defined foot-print. These include the use of dispensing equipment such as a piston pump, syringe pump or on-demand ink-jet printer.

5           In a further embodiment, a flexible tape containing one or more reagents may be laminated to another flexible tape on which is printed a series of electrodes. Instead of cutting out individual sensors, the laminate (comprising a row or series of sensors) may be used sequentially, e.g. on being dispensed from a suitable dispenser. For this purpose, whether or not as a laminate, a  
10   tape of the invention may be provided as a roll, and stored in sealed cassettes which may also contain desiccant. In use, the cassette may be inserted into a automatic dispenser from which the tape is wound out automatically by an indexing mechanism to reveal sequentially the discrete sensors. The action of this instrument is therefore analogous to the action of a film in a camera. In this  
15   embodiment, the tape may also contain a red blood cell-lysing reagent such as saponin, in order to reduce the effect of haematocrit and haemoglobin in a whole blood sample. The tape may be further protected from moisture by being covered with a peelable film (e.g. of aluminium) that is automatically peeled off when the tape is dispensed from the cassette. When the sample is applied to  
20   the sensor, the amount of analyte of interest in the sample may be determined electrochemically. Such determination can be conducted by known methods.

The following Example illustrates the invention.

#### Example

25           A conductive ink material is printed onto a non-conducting polyester sheet material by a screen-printing process. The conductive ink material consists of a mixture of graphite and carbon particles and a polymer binder in an organic solvent. After deposition of the conductive ink, solvents are removed in a forced air oven. A silver/silver chloride reference/counter electrode is printed onto one of each pair of printed carbon electrodes followed  
30   by a non-conducting ink layer to define the contact pads and the sensor area.

A mediator such as Meldola Blue, Nile Blue or other suitable dye and the enzyme co-factor nicotinamide adenine dinucleotide (NAD) are deposited onto

the carbon electrode. Alternatively, the NAD is applied separately over the mediator from an aqueous ink.

The enzyme glucose dehydrogenase is deposited as uniform spots on a monofilament polyester mesh tape. This is achieved as follows:

- 5           (a) in a contact mode, where a drop formed at a dispenser tip in close proximity to the mesh is allowed to be transferred to the mesh by touching off the drop onto the mesh surface; or
- (b) in a non-contact mode, where a drop formed by an ink-jet print-head or other orifice above the mesh is dropped onto the mesh  
10           from a distance under conditions which do not cause it to penetrate the mesh.

Upon drying, the spots spread to cover an area defined partly by the characteristics of the mesh weave and partly by the application conditions. Typically the areas covered by a 500 nL drop is 1.3 x 1.2 mm. The mesh tape  
15 is allowed to dry at room temperature.

The enzyme-modified mesh tape is then laminated onto the modified sheet of devices and secured further by a non-conducting print. Finally, a cover tape is laminated on tope of the mesh. The sheets of devices are disc cut into individual devices. In an alternative device format, the laminated sheets are  
20 wound and included in a cassette type unit, allowing a single device to be used by a wind-on mechanism similar to a camera film-winding system.



CLAIMS

1. A test strip comprising a support carrying an active electrode and a counterelectrode, and a layer of material within which a small volume of liquid to be tested can be distributed and provide contact between the electrodes, and  
5 wherein an analyte-specific reagent is coated on the material.
2. A test strip according to claim 1, wherein the reagent is at least one component of a redox reaction, e.g. one or more of an enzyme, a mediator and/or co-factor for the enzyme.
3. A test strip according to claim 2, wherein the at least one component  
10 comprises the enzyme.
4. A test strip according to claim 2 or claim 3, wherein the enzyme is glucose oxidase or glucose dehydrogenase.
5. A test strip according to any preceding claim, wherein the material is a monofilament mesh or membrane.
- 15 6. A flexible tape of a material within which liquid can be distributed and on which are coated discrete areas of at least one component of a redox reaction.
7. A flexible tape according to claim 6, wherein the material is a monofilament mesh or membrane.
8. A container containing a wound tape according to claim 6 or claim 7.
- 20 9. A container according to claim 8 also comprising automatic dispensing means.
10. A method for testing a liquid for the presence of an analyte, which comprises contacting the liquid with a test strip according to any of claims 1 to 5, and detecting the current.
- 25 11. A method according to claim 10, wherein the liquid is blood and the analyte is glucose.

# INTERNATIONAL SEARCH REPORT

International Application No.  
PCT/GB 99/03764

A. CLASSIFICATION OF SUBJECT MATTER  
IPC 7 C12Q1/00 G01N35/00 G01N27/30 G01N27/327

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)  
IPC 7 C12Q G01N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 97 02487 A (BOEHRINGER MANNHEIM CORP) 23 January 1997 (1997-01-23) page 1, line 33 -page 8, line 28; figure 1; table 1	1-5, 10, 11
Y	—	7-9
X	US 5 169 600 A (ISHIZAKA HIDEO ET AL) 8 December 1992 (1992-12-08) column 8, line 15-34	1
Y	—	7-9
X	US 5 779 867 A (SHIEH PAUL) 14 July 1998 (1998-07-14) column 4, line 14-21; claims 1-4 abstract	1-5, 10, 11
	— -/-	

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

### \* Special categories of cited documents:

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier document but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- "&" document member of the same patent family

Date of the actual completion of the international search

11 February 2000

Date of mailing of the international search report

24/02/2000

Name and mailing address of the ISA  
European Patent Office, P.B. 5818 Patentlaan 2  
NL - 2280 HV Rijswijk  
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,  
Fax: (+31-70) 340-3016

Authorized officer

Brison, O

## INTERNATIONAL SEARCH REPORT

Int. Patent Application No.

PCT/GB 99/03764

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 798 031 A (CHARLTON STEVEN C ET AL) 25 August 1998 (1998-08-25) abstract	1-5,10, 11
A	column 5, line 22-25	6-8
Y	US 5 628 890 A (CARTER NIGEL F ET AL) 13 May 1997 (1997-05-13) column 3, line 41 -column 4, line 10 abstract	1-5,10, 11
Y	EP 0 230 472 A (MATSUSHITA ELECTRIC IND CO LTD) 5 August 1987 (1987-08-05) page 7, line 14-25	1-5,10, 11
X	EP 0 593 096 A (MEDISENSE INC) 20 April 1994 (1994-04-20) page 6, line 57 -page 7, line 3; figure 3	6-9
A	page 2, line 28-50	1
X	US 4 218 421 A (MACK JOHN C JR ET AL) 19 August 1980 (1980-08-19) column 2, line 43 -column 4, line 53	6-9
X	US 5 679 311 A (HARTTIG HERBERT ET AL) 21 October 1997 (1997-10-21) abstract; figure 2A	6-8
A,P	WO 99 13100 A (ABBOTT LAB) 18 March 1999 (1999-03-18) abstract; figure 1	1

# INTERNATIONAL SEARCH REPORT

Information on patent family members

Int. J. Appl. No.

PCT/GB 99/03764

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9702487 A	23-01-1997	US 5762770 A AU 712527 B AU 6345196 A CA 2224308 A EP 0874984 A	09-06-1998 11-11-1999 05-02-1997 23-01-1997 04-11-1998
US 5169600 A	08-12-1992	JP 1020454 A JP 2119175 C JP 8020453 B JP 1020455 A JP 2119176 C JP 8020454 B JP 1080865 A JP 1080866 A DE 3853700 D DE 3853700 T EP 0299519 A US 5122343 A	24-01-1989 06-12-1996 04-03-1996 24-01-1989 06-12-1996 04-03-1996 27-03-1989 27-03-1989 08-06-1995 07-09-1995 18-01-1989 16-06-1992
US 5779867 A	14-07-1998	US 5522977 A US 5645710 A	04-06-1996 08-07-1997
US 5798031 A	25-08-1998	AU 6482198 A CA 2236132 A EP 0878708 A JP 10318971 A NZ 329793 A	12-11-1998 12-11-1998 18-11-1998 04-12-1998 25-11-1998
US 5628890 A	13-05-1997	CA 2159553 A JP 9222411 A	30-03-1997 26-08-1997
EP 0230472 A	05-08-1987	JP 2624236 B JP 62232554 A JP 6048256 B JP 61294351 A JP 1915067 C JP 6040088 B JP 62108145 A JP 1949170 C JP 6076984 B JP 62108146 A JP 1915084 C JP 6040089 B JP 62137559 A DE 3687646 A WO 8607632 A US 4897173 A US 5185256 A	25-06-1997 13-10-1987 22-06-1994 25-12-1986 23-03-1995 25-05-1994 19-05-1987 10-07-1995 28-09-1994 19-05-1987 23-03-1995 25-05-1994 20-06-1987 11-03-1993 31-12-1986 30-01-1990 09-02-1993
EP 0593096 A	20-04-1994	AU 622196 B AU 3822089 A CA 1313397 A EP 0352138 A JP 2112752 A US 5126034 A	02-04-1992 01-02-1990 02-02-1993 24-01-1990 25-04-1990 30-06-1992
US 4218421 A	19-08-1980	NONE	

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/GB 99/03764

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5679311 A	21-10-1997	DE 4326339 A EP 0637749 A JP 2610109 B JP 7077528 A US 5609823 A	09-02-1995 08-02-1995 14-05-1997 20-03-1995 11-03-1997
WO 9913100 A	18-03-1999	AU 9129798 A	29-03-1999

**THIS PAGE BLANK (USPTO)**